Chapter 4
PROPOSED MINIMUM FLOWS AND LEVELS CRITERIA

The following chapter presents the MFL criteria as required in Chapter 373, Florida Statutes for the Caloosahatchee River and Estuary. This chapter provides a summary of the scientific approach and technical relationships that were evaluated in defining significant harm for the water body and a detailed presentation of the proposed MFL criteria with supporting documentation. This section also describes changes and structural alterations (considerations as set forth in Section 373.0421(1)(a), F.S.) that have occurred in the watershed and existing hydrologic constraints. For the purposes of this study, significant harm is defined as a loss of specific water resource functions resulting from a change in surface water or ground water hydrology that takes multiple years for recovery (see Chapter 1 for further discussion of the definition of significant harm).

The purpose of the following sections are to (a) identify the watershed considerations and water resource functions that were evaluated in the development of the proposed minimum flow criteria for the Caloosahatchee River and Estuary; (b) identify the technical relationships considered in defining significant harm; (c) provide a definition of significant harm; and (d) provide a discussion of the District's proposed MFL Recovery and Prevention Strategy.

WATERSHED CONSIDERATIONS AND RESOURCE FUNCTIONS

The Caloosahatchee River system can be divided into four components as follows that affect, or are affected by the need to establish Minimum Flows and Levels (MFLs).

- Lake Okeechobee
- The River Itself,
- The River and Estuary Watershed
- The Estuary

Based on examination of the functions of these components, a Caloosahatchee River and estuary MFL is proposed, based on providing minimum flows necessary to protect the estuary from significant harm. The analysis determined that the Caloosahatchee estuary is highly dependent upon sufficient water flows and is sensitive to high salinity levels. The health of this estuary is also an indicator of health of the watershed. The estuary also has a high probability of experiencing significant harm due to lack of sufficient freshwater flows before structural solutions that part of the Comprehensive Everglades Restoration Plan are complete. Short-term and long-term recovery strategies are proposed.

Lake Okeechobee

Major Features and Uses

Lake Okeechobee provides a source of freshwater flow to meet water needs in the Caloosahatchee River basin during dry periods and a source of excess during wet periods. The amount of excess water discharged from Lake Okeechobee depends on the Lake's regulation schedule and conveyance capacities to alternative discharge sites. The regulation schedule is based on the need to protect Lake levees from storm damage. The use of alternative discharge sites depends on the ability to discharge water south through the EAA and the other primary emergency release site -- the St. Lucie Canal and estuary. Availability of water from Lake Okeechobee during dry periods is constrained by regional water supply needs. Water from the Lake is also used to meet reservations and Minimum Flows and Levels established for the Lower East Coast Planning Area, most notably Lake Okeechobee, the Everglades and the Biscayne Aquifer. For a detailed discussion and consideration of these functions and related issues, see the MFL document developed for Lake Okeechobee, the Everglades and the Biscayne Aquifer (SFWMD 2000e)

Water Resource Functions.

The primary functions of Lake Okeechobee that need to be considered in the development of MFLs for the Caloosahatchee River and estuary include water supply, flood protection, navigation, recreation, natural systems, protection of fish and wildlife habitat and water quality.

Water Supply. Constraints on providing MFL deliveries from Lake Okeechobee to the Caloosahatchee River are based on consideration of the needs of the lake as a water supply reservoir for South Florida. Sufficient water must be stored in the lake to meet water reservations, MFL and water supply needs of the LEC, as well as to prevent saltwater intrusion of Lower East Coast coastal canals and the Biscayne aquifer. The amount of water in the lake available for releases to the estuary is dependent on discretionary release policies contained within the regulation Water Supply and Environmental (WSE) schedule (USACE 2000b), the amount of water stored in the Lake based on Supply-Side Management policies (Hall, 1991), and the physical constraints of release structures. The average requirement from Lake Okeechobee to meet public water supply demands in the Caloosahatchee basin is currently about 13,000 acre-ft per year. The average amount needed for agricultural use is about 111,000 acre-ft per year (SFWMD, 2000d).

Flood Protection. (no significant constraints on ability to provide MFL releases)

Navigation. Maintenance of minimum levels in the Lake and perimeter canal needed to provide navigational access. When lake levels fall below 12.56 ft. NGVD, navigation of the Okeechobee Waterway becomes impaired (USACE, 1957).

Recreation. Impacts on recreational uses may occur in the Lake due to low water levels (below 11.0 ft. NGVD) and these would be aggravated by additional water releases to the Caloosahatchee River.

Protection of Fish and Wildlife Habitat. Maintenance of sufficient water depth and hydroperiod within the Lake is needed to protect littoral zone plant and animal communities and fisheries resources. Eleven feet NGVD is also the minimum level for protecting Lake Okeechobee's littoral zone (SFWMD 2000e).

Water Quality. When discharge from Lake Okeechobee is the primary source of water being discharged at S-79, water quality is better than when most of the water comes from the Caloosahatchee Basin. Nutrient concentrations are higher in water from the watershed than in water derived from the Lake.

Other Considerations. Other demands on the lake include the need to provide water supply to Everglades Agricultural Area, the Seminole Indian tribe, Everglades National Park and the Caloosahatchee and St. Lucie basins.

Operational Protocols Established to Protect Resources

Four primary protocols are used by the District and the USACE to protect resources of Lake Okeechobee as follows:

- MFL criteria provide a basis to protect resources in the lake from significant harm;
- A regulation schedule is used to manage water levels in the lake and requires periodic discharges of excess water from the lake to coastal estuaries to protect integrity of the levees.
- A Supply-Side Management Plan (Hall, 1991) is used to manage water deliveries from Lake Okeechobee during dry periods.
- A newly adopted WSE (Water Supply and Environmental) schedule has been adopted for Lake Okeechobee that provides additional flexibility for discretionary releases of water from the Lake to provide environmental benefits (USACE 2000b)

Caloosahatchee River

Major Features and Uses

The Caloosahatchee River watershed covers approximately 1,400 square miles and includes significant areas in Glades and Hendry counties, a part of Lee County and a small part of Collier, Charlotte and Palm Beach counties.

The primary system consists of the C-43 Canal (Caloosahatchee River) and the C-19 canal, which were excavated as part of the Central and South Florida Flood Control Project (USACE, 1957) (**Figure 5)**. There are several structures on these canals, which are designed to maintain upstream water levels (**Table 7).** The canals and water control structures were designed to provide 33 cfs per square mile or 1.25 inches of drainage for the Caloosahatchee watershed.

The River itself is divided into two segments as water flows from east to west. The eastern segment extends from the Moore Haven Locks at the edge of Lake Okeechobee for a distance of 16 miles to the Ortona Locks, near LaBelle. The western segment extends for 28 miles from the Ortona Locks to the Franklin Locks. Under normal operating conditions, water levels in Lake Okeechobee may range from 13 to 17 ft NGVD. Downstream from the Moore Haven Locks, water levels are maintained from 10.8 to 11.3 ft NGVD. The western segment of the River is generally maintained at elevations from 2.8 to 3.4 ft NGVD **(Table 7).**

Table 7 Operating Schedules for the Primary Canal System

Structure	Canal	Operating Rule
S-77	C-43	Discharge rule follows Lake Okeechobee regulation schedule.
S-78	C-43	Maintain upstream canal stage between 10.8 and 11.3 feet NGVD
S-79	C-43	Maintain upstream canal stage between 2.8 and 3.4 feet NGVD. Rules allow lowering stage to 2.2 feet to accommodate anticipated runoff, however stage maintained above 2.5 feet to provide water for Lee Co. water supply intakes.
S-47D	C-19	Maintain upstream water between 12.5 and 13.0 ft NGVD
S-47B	C-19	Maintain upstream water between 14 and 15.5 ft. NGVD When below
S-342	C-19	Maintain upstream water above 16 ft NGVD
C-5		Release water from lake when Lake Okeechobee is above 14.5 and basin below 12.0 ft NGVD
C-5A	L-41	Release water from lake when Lake Okeechobee is above 14.5 and basin below 12.0 ft NGVD
S-235	C-43 & LD1	Kept open when possible to provide water and drainage for S-4 basin. Stage maintained in S-4 borrow canals 11-14 feet NGVD

The River functions as a conveyance channel to distribute water to various users during dry periods, remove excess stormwater from the basin during wet periods, convey regulatory discharges from Lake Okeechobee to tide water, and provide freshwater flows needed to maintain a highly-productive downstream estuary. The River also contains significant wetland systems in the Lake Hicpochee area in the eastern (upstream) river basin and along the shore of various oxbows in the western portion of the River. These areas provide food and habitat for wading birds and other water-dependent plants and animals, including some threatened and endangered species. The River provides navigational access from Lake Okeechobee through LaBelle to Fort Myers and adjacent communities and supports recreational fishing and boating. Water is also removed from the River through intakes upstream from the Franklin Locks to recharge wellfields owned by Lee County and the City of Fort Myers. Water quality problems in the River (excess salinity or algal blooms) may require occasional releases from Lake Okeechobee to "flush out" the contaminated water.

Water Resource Functions

The primary functions of the river that need to be considered in the development of MFLs thus include water supply, flood protection, navigation, recreation, protection of natural systems and water quality.

Water Supply. Total water needs of agricultural and urban users within the Caloosahatchee Basin were identified in the Caloosahatchee River Water Management Plan (SFWMD, 2000d). Current (1995) agricultural water use was projected to range from 225,000 to 290,000 acre-ft per year. Public Water Supply use was estimated to range from 10-16 MGD (11,000-18,000 acre-ft/year). The ability to meet existing and future water supply needs in this basin was addressed in the LEC and LWC Regional Water Supply plans. (SFWMD 2000b and 2000c). In the short run, these needs will be met through water generated in the basin and water delivered from Lake Okeechobee. In the longer term, completion of regional water storage projects proposed in the Comprehensive Everglades Restoration Plan (CERP) and water supply plans will allow future water needs to be met almost entirely from sources within the Caloosahatchee River watershed (USACE and SFWMD 1999). At the maximum allowable stages within the basin (3.4 ft NGVD above the Franklin Locks and 11.3 ft NGVD above the Ortona Locks), the River contains no significant water storage, so demands are met by periodically releasing water from Lake Okeechobee. The minimum water deliveries that are required to the River to meet water supply demands in the Caloosahatchee basin vary by season, with an average of 600 cfs and a maximum of 2800 cfs during a 1-in-10 year drought event (SFWMD 2000d)

Flood Protection. The need to provide flood protection within the basin requires maintenance of certain maximum levels within the River and thus places an upper limit on the amount of water that can be stored in surface water canals in the basin. At the minimum allowable stages within the basin (2.2 ft NGVD above the Franklin Locks and 10 ft NGVD above the Ortona Locks), the River contains no appreciable flood storage, so excess runoff is discharged to tide.

Navigation. Maintenance of minimum levels in the River is needed to provide navigational access for the Okeechobee Waterway and provides a lower limit for withdrawals from the River. The lowest levels that can be maintained in the River without impairing navigational use are 10 ft NGVD above the Ortona Locks (25 foot channel depth) and 3 ft NGVD above the Franklin Locks (27 foot channel depth). Water is also released from the River to the estuary when boats pass through the locks. Lockages may be restricted during periods when water levels are low in Lake Okeechobee or when saltwater intrusion affects local water supply intakes near S-79.

Recreation. Impacts on recreational uses may occur in the river due to low flows, increased incidence of blue-green algae blooms and degraded water quality conditions that may impact fisheries. In general, steps taken to address water quality problems in the river (see below) will also improve fisheries.

Natural Systems. Maintenance of sufficient water levels and flows in the River are needed to protect plant and animal communities and fisheries resources in oxbows and adjacent riverine wetland systems. In general, maintenance of sufficient water levels in the river that are needed to provide water supply and meet navigational requirements will also be sufficient to protect natural systems.

Water Quality. Water in the River is generally of good quality, with the exception that the lower stretches of the River, immediately upstream from the Franklin Locks in the area where water is withdrawn for water supply (Lee County) to recharge local wellfields (City of Fort Myers), may occasionally become saline above the locks or may experience periodic algal blooms that impair its use for public water supply (Miller 1980).

Operational Protocols Established to Protect Resources

During such periods when poor water quality conditions occur in the vicinity of water utility intakes, upstream of the Franklin locks, releases of fresh water are made from Lake Okeechobee to "flush" poor quality water downstream. Such releases generally are made only once or twice during the dry season. These operational protocols have been developed and are implemented by the SFWMD and The United States Army Corps of Engineers (USACE) to address water quality problems in the River. In the past, 3 to 4 day discharges from S-79 have been made to reduce salinity at the Lee County water plant during the dry season. The rate of discharge ranged from about 3,000 to 7,700 cfs per day. The total volume of these discharges ranged from 15,000 to 25,000 ac ft of water per event. Experimental releases from S-79 have been made to try and reduce the volume of water needed to flush the saltwater downstream and implement the discharges in a more environmental friendly manor. Results indicate that flows for 3 to 4 days are needed as follows: Day 1 – 1000cfs, Day 2 – 2800 cfs, and Day 3 – 3100 cfs with Day 4 (2000 cfs) optional depending on salt readings at the water plants. The total volume for such a 3-day event is 13,800-acre feet (see **Table 2**)

Chapter 7 of the Lake Okeechobee Master Water Control Manual (USACE 20000b) was recently revised by the USACE to include the new regulation schedule for Lake Okeechobee (WSE). The following are excerpts from pages 7-2 and 7-3 (paragraphs 7-02e and 7-02f):

Algae Blooms - During the seasonally dry months from December to April of each year, the Caloosahatchee River flow diminishes to the point that an occasional severe algae bloom develops in the river above Franklin Lock and Dam (Miller 1980). The City of Ft. Myers and Lee County both have municipal water intakes in this area which could be clogged by the algae. Short-term high rates of discharge from Lake Okeechobee are required to break up the algae bloom. This is done by the Corps whenever requested by the SFWMD.

Salinity Intrusion - During the extreme dry months of April and May the Caloosahatchee River flow may drop to near zero. When this condition prevails, navigation lockages through the W.P. Franklin Lock allow a saltwater wedge to move upstream. More lockages result in more salt water moving upstream. Eventually, the chloride content of the water entering the municipal water intakes of Ft. Myers and Lee County exceeds the drinking water standard of 250 ppm. When this happens, SFWMD requests the Corps to flush out the salt water with a short-term high rate of discharge from Lake Okeechobee. A pulse release type of approach and a smaller steady release, such as 300 cfs monthly average, have also been used for these events to benefit the estuaries.

Reduced Lockages. During a declared water shortage period, the SFWMD requests that the Corps go to reduced hours of lockages.

These procedures have worked effectively in the past to protect the quality of water in the river as a source of supply for Lee County and the City of Fort Myers water utilities.

Watershed

Major Features and Uses.

The River watershed upstream of Franklin Locks is largely developed for agricultural use, including citrus, row crops and cattle ranching (unimproved pasture) with very limited urban development, primarily near the towns of Moore Haven and LaBelle. The 1995 land use in the Caloosahatchee Basin is summarized in **Table 8** (SFWMD 2000d). Total water use from surface and groundwater sources in the eastern and western basins is estimated as 582,000 acre-ft/yr. The watershed is the primary source of base flow to the river, estimated as 918,000 acre-ft of surface water runoff (SFWMD 2000d) from measured sources and approximately and equal amount of flow from unmeasured sources and groundwater seepage through the shallow aquifer (Fan and Burgess, 1983). Land uses in the watershed create a substantial demand for supplemental irrigation water during dry periods and require capacity for releases of stormwater to the River during wet periods to prevent flooding. Runoff from agricultural land also results in periodic water quality degradation of the River due to contamination by nutrients and pesticides (Miller 1980; Degrove and Nearhoff 1987; Baker 1990; Doering and Chamberlain, 1999).

The estuary watershed downstream of the Franklin Locks also plays an important role in this system. This area provides base flows of surface water runoff and groundwater that depend on local rainfall conditions and may have significant effects on salinities in the tidal portion of the estuary. Large amounts of runoff may be generated from these basins during flood events. In addition, urban development in this area may contribute to water quality problems in the estuary and adjacent waters. Docks and marinas (largely for recreational use, but also including some significant commercial fishing traffic) in this basin are a primary destination for boats leaving and entering the river and traffic from the Gulf of Mexico and adjacent areas. Portions of this subbasin are also within the service area for utilities that withdraw water from the River and thus the dense urban and residential populations contribute to the high dry-season water demands from the River.

Table 8. Land Use and Sources of Water Supply within the Upper Caloosahatchee Basin

Basin	Water Supply Source	Land Use (acres)								
		Citrus - crown flood irrigated	Citrus - microjet irrigated	Sugar Cane sub-seepage irrigated	Tomato - 4 month with micro-spray	Pasture - (assumed to be like citrus)	Other Pasture	Upland Forest	Wetland	TOTAL
ecal-d	C-43	4,754	5,231	20,590	4,082	4,836	67,734	12,125	19,859	*139,211*
wcal-d	C-43	8,153	8,970	0	2,811	3,231	45,593	7,615	8,534	*84,907*
ecal-gw	Ground water	6	7	282	147	2,555	41,281	19,275	15,628	*79,179*
wcal-gw	Ground water	5,477	6,026	0	4,792	7,542	118,816	72,094	57,054	*271,799*
ecal-lok	Lake Okee.	0	0	3,057	18	258	3,157	503	748	*7,741*
TOTAL		***18,390***	***20,234***	***23,929***	***11,850***	***18,422***	***276,580***	***111,612***	***101,822***	***582,838***

Water Resource Functions

The primary functions that need to be considered in the watershed during development of MFLs thus include protection of water supply, flood protection, protection of natural systems and water quality.

Protection of Water Supply. An estimated 111,000 acre-ft of surface water from C-43 canal is used in the eastern and western Caloosahatchee River Basins each year for irrigation of agricultural lands and 9,000 acre-ft of surface water from Lake Okeechobee is used in the eastern basin. Significant amounts of groundwater (36,000 acre-ft) are used for agricultural irrigation. Limited amounts (16 MGD or about 17,000 acre-ft/yr) of groundwater is consumed for urban uses by Lee County and the City of Fort Myers utilities (SFWMD, 2000d). A year-round average base flow of about 190 cfs is thus required in the river to meet these average annual water supply needs in the watershed

Flood Protection. The need to provide adequate drainage and flood protection within the basin requires that excess water from the watershed is discharged to the river. That portion of irrigation water and excess rainfall from the eastern and western basins that is not lost to evaporation, is discharged to the River as runoff and contributes 918,000 acre-feet or about 1,300 cfs of average annual flow. Runoff from the tidal basin contributes an estimated significant (but not documented) amount to the annual flow on average and may contribute substantial flows for several days or weeks during peak discharge periods.

Protection of Fish and Wildlife Habitat. Maintenance of sufficient water levels and flows in the upstream watershed are needed to protect wetland plant and animal communities and fisheries resources in adjacent wetlands. The eastern and western Caloosahatchee River basins contain approximately 102,000 acres of lakes and wetlands and 112,000 acres of upland plant communities that provide habitat for native fish and wildlife, including a number of threatened and endangered species. In general, maintenance of sufficient water in the river needed to provide water supply and to meet navigational requirements will also be sufficient to protect natural systems in the watershed. The District's Consumptive Use Permit criteria are designed so that withdrawals will not allow more than 1 foot of drawdown to occur beneath wetlands (SFWMD 1997b).

Protection of Water Quality. Water in the River is generally of good quality, with the exception that the lower stretches of the River, immediately upstream from the Franklin Locks in the area where water is withdrawn to recharge local wellfields, may occasionally become saline due to intrusion of saltwater above the locks or may experience periodic algal blooms during low flow or stagnant conditions that impair its use for public water supply. The quality of runoff water from the eastern water sheds is periodically contaminated by pesticides and suspended solids. Runoff quality from coastal watershed is largely unknown, but may contain significant contamination from fertilizers, pesticides, oil and gas residues and commercial/industrial chemicals.

Operational Protocols Established to Protect Resources

The primary operational actions that are taken by the District and USACE to protect resources in the watershed are designed to address the drainage (flood control) and water supply functions

- Water levels in the primary canal system may be lowered prior to the onset of a major storm in order to provide additional storage for flood waters in the River channel.
- Water deliveries may be made from Lake Okeechobee during dry periods to meet supplemental irrigation demands.

Caloosahatchee Estuary

Major Features and Uses.

The Caloosahatchee Estuary provides a water conveyance and navigational link from the River to the Gulf of Mexico and supports a highly productive estuarine ecosystem, including both sport and commercial fisheries. Failure to provide sufficient freshwater flow adversely impacts this system by destroying its estuarine character, shifting the benthic communities that provide the normal basis of the food chain from estuarine to marine species. The low-salinity or freshwater habitat in the upper reaches of the estuary also provides some degree of protection for developing stages and juveniles of both estuarine and marine species. Too little discharge of freshwater may thus result in loss of estuarine species of plants and animals and a decline in species diversity. Tape grass (*Vallisneria*) has been identified as a key species in this system that provides important benthic habitat downstream from the Franklin Locks. This species is proposed as an overall indicator of estuarine "health." Field and laboratory research, modeling and hydrologic studies have been conducted to determine flow rates that are needed to support this community.

Water Resource Functions.

The primary functions that need to be considered in the estuary during development of MFLs thus include protection natural systems and water quality.

Protection of Fish and Wildlife Habitat. Maintenance of sufficient flows of freshwater into the estuary is needed to protect plant and animal communities and fisheries. The environmental needs of the Caloosahatchee estuary have been estimated as 450,000 acre-ft/year (400 MGD), while actual flows to the estuary average about 650,000 acre-ft/year (580 MGD) (SFWMD 2000b). In general, maintenance of sufficient flow to meet the needs of the estuary will also meet upstream water supply and navigational requirements and address water quality concerns in the river.

Water Quality. Water in the Estuary is generally of good quality. Releases of freshwater from coastal rivers and canals generally contain high levels of nutrients and trace metals that increase primary productivity in adjacent estuaries and coastal waters.

Operational Protocols Established to Protect Resources

The primary operational protocols that have been adopted to protect the estuary are designed to limit the rate of discharge for regulatory releases. These considerations have been incorporated into the zone designations, discretionary releases policies, water release schedules and and pulse release protocol of the Lake Okeechobee Regulation Schedule (USACE 2000b).

Summary and Conclusions

Based on evaluation of the functions and considerations of the river and watershed, District staff reached the following conclusions:

- Due to the highly altered condition of the river and watershed and human management of the system, District staff feel that considerations, as defined in Section 373.0421(1)(a) F.S., adequately address the changes and alterations in water resource functions applicable to the Caloosahatchee watershed and river.
- Based on the full range of functions provided by the River and watershed, it was determined that these systems are highly modified from their historic condition. Rivers and streams have been channelized, the watershed has been greatly expanded by connection to Lake Okeechobee and water control structures have been added to create a series of impoundments rather than a

free-flowing water course. The present day hydrology of the system is carefully managed and regulated to ensure that navigation, water supply and drainage/flood control functions are met on a continuing basis.

- The upstream watershed also contains significant fish and wildlife resources that need to be addressed. Although these natural systems may not be performing the same functions at the same levels as occurred historically, current management practices in the basin appear to provide adequate protection.
- In spite of the protection of most resource functions of the River and watershed provided by current management practices, at least two functions seem to be occasionally compromised to an extent that could potentially constitute harm as follows:

    1. Impacts on the water supply function, i.e. the ability to provide adequate quality water to meet urban water supply needs upstream of Franklin locks due to periodic deterioration of water quality, and
    2. Impacts on the navigation and recreation functions derived from the need to periodically reduce lockages through S-79 as a means to control upstream movement of saline water.

- Actions will be taken to alleviate these problems over the next 10 to 20 years through the Comprehensive Everglades Restoration Project. In the meantime, The district is developing and implementing operational protocols for water resource protection purposes to achieve an optimal salinity envelope, with the existing constraints and alterations in the system, prior to the structural solutions under the CERP. Maximum discharges from Lake Okeechobee will be mitigated in the future through implementation of WSE (formally initiated June 2000) Lake Okeechobee Regulation Schedule that recognizes the ability to provide MFL releases to estuaries when Lake levels are in discretionary release zones.
- In recent years, attention has been given to the need to manage resources in the estuary more effectively during low flow conditions to protect water quality and fish and wildlife habitat functions of these sensitive systems. Past management practices have not provided adequate protection for fish and wildlife habitat functions in the estuary during periods of deficient rainfall. Due to development and water use in the watershed, dry season basin flows to the estuary have been reduced and access of estuarine species to fresh water environments has been greatly reduced
- A rationale has been developed in this report, based on a survey of resources available within the region, historic conditions and comparison with similar river systems, to provide sufficient flow in the river during the winter and spring months that will maintain a viable low salinity environment downstream from the S-79 structure.
- Evidence is also presented to show that providing flows necessary to maintain such a community in the estuary will also help reduce the occurrence of poor water quality conditions (elevated chloride concentrations and algae blooms) in the river, the need to make special water releases from Lake Okeechobee, and the need to limit lockages.

- The Caloosahatchee estuary is highly dependent upon sufficient water flows and is very sensitive to high salinity levels. The health of this estuary is also an indicator of health of the watershed, since it receives runoff from the entire basin, and it serves as a nursery ground for many estuarine and coastal plants and animals. This estuary also has a high probability of experiencing significant harm due to lack of sufficient freshwater flows before the CERP structural solutions are complete. A proposed Caloosahatchee River and estuary MFL and associated management strategy were therefore developed, based on providing minimum flows necessary to protect the estuary from significant harm.

TECHNICAL RELATIONSHIPS CONSIDERED IN DEFINING SIGNIFICANT HARM

Sources of Additional Information

Results of the literature search (Estevez, 2000) produced a bibliography containing approximately 300 citations. Major findings of the literature review were that very few published or unpublished accounts exist to inform the establishment of minimum flows in highly altered riverine estuaries, especially when honoring the constraint that such minimum flow methods rely on living resources (Estevez, 2000).

Once the water resource functions of the river and estuary that needed to be protected by establishment of the MFL were identified, specific technical relationships were developed and considered to define significant harm for the water body. Lacking specific guidance from previous studies, the following process was used to develop these technical relationships with supporting documentation. These following sources of information were reviewed:

1. Development of a Valued Ecosystem Component (VEC) approach (EPA, 1987) to establish a minimum flow regime at S-79 that will protect the system from significant harm. (Chamberlain et al. 1995; Haunert et al. in review).
2. In addition to the literature search (Estevez 2000), District staff reviewed information available concerning key species or groups of organisms that may benefit from using *Vallisneria* grass bed communities within the Caloosahatchee estuary, including their life histories and tolerance to low salinity levels.
3. Review of available information obtained from the District's Caloosahatchee estuarine research programs including results from field, laboratory mesocosm, and growth rate studies conducted within the watershed.
4. Development of an empirical relationship between salinity at a given location in the estuary as function of flows through S-79.
5. Development of a Vallisneria growth rate algorithm relating changes in blade length, blade density and shoot density to salinity at various locations in the estuary.
6. The above algorithms were converted to computer code and incorporated into the South Florida Water Management Model (SFWMM) to simulate Vallisneria growth response under different flow scenarios for current (1995) base case and future 2020

with Restudy conditions (See memos from Peter Doering, March 22, 2000, and Ken Konyha, June 29, 2000, Appendix A).

Valued Ecosystem Component (VEC) Approach

The SFWMD's Caloosahatchee Estuary research program supports application of a resource-based management strategy similar to the Valued Ecosystem Component (VEC) approach developed by the U.S. Environmental Protection Agency as part of its National Estuary Program (USEPA 1987*)*. For the purposes of this study, the VEC approach is based on the concept that estuary management goals can best be achieved by providing suitable environmental conditions for selected key species or key groups of species that inhabit the estuary. In this case, the key species identified to be protected against significant harm is submerged aquatic vegetation (SAV), specifically *Vallisneria sp*. (commonly known as tape grass or wild celery) present within the upstream fresh/brackish water portion of the river. Submerged aquatic vegetation are important to the ecosystem in that they sustain an important water resource function by providing food, and habitat for forage fish, shellfish, and serve as nursery areas for many juveniles species of fish that are recreationally or commercially important (Day *et al*., 1989; Heck et al., 1995; Kemp et al., 1984; Lubbers et al. 1990; Orth et al. 1984). This approach assumes (a) that environmental conditions suitable for VEC will also be suitable for other desirable species; and, (b) that enhancement of VEC will lead to enhancement of other species. Through this strategy, management objectives will be attained by providing a minimum flow that will protect this community against significant harm.

The VEC approach was applied to the Caloosahatchee River and Estuary based on the following scientific assumptions: Seagrass (*Thalassia testudinum, Halodule wrightii*) meadows are prevalent at the seaward/outer end of the system where salinity can be significantly impacted by high volumes of freshwater discharged to the estuary from S-79 or from local basins. Therefore, these seagrass communities represent the VEC for assessing the impact of high flows within the estuary. At the other end of the spectrum, beds of *Vallisneria americana* are prominent in the fresh-brackish water (low salinity) portion of the inner estuary. These communities are sensitive to increased salinity values that result from reduced volumes of water low discharged to the estuary during the dry season. Since this report focuses on establishing a minimum flow that will the protect the ecosystem against significant harm, *Vallisneria* was selected as the VEC of choice in that it represents a number of the primary water resource functions that need protection during low flow periods. The District has published several studies using this resource-based approach to define a preliminary estimate of optimum freshwater flows that should be delivered to the Caloosahatchee Estuary (Chamberlain *et al.* 1995, Chamberlain and Doering 1998a, 1998b). Major findings of this work were:

- A minimum inflow of 300 cfs will not be harmful to *Vallisneria* communities and other estuarine biota, however inflows greater than 2,500-3,000 cfs will be detrimental to these communities anytime of the year (**Table 9).**

Table 9. Summary of Recommended Flows through Structure S-79 for Maintaining Ecological Health of Key Species within the Caloosahatchee River/Estuary System.

Species	Low flow Limit (cfs)	Preferred Inflow range (cfs)	Upper Inflow Limit (cfs)	Important Months
Vallisneria	300	300-800	<3,000	Dry Season (Nov-May)
Halodule, Thalassia	---	----	3,000	
Fish (general)	300	300-1,300	3,000	Dry season
Larval Fish	---	300-800	<2,500	March- July
Fish eggs	---	150-600	<2,500	All Year
Pink Shrimp & Blue Crabs	300	300-800	<3,000	All year
Shrimp & Crab larvae	---	<1,300	<2,500	All year; (esp. spring-July)
Benthic invertebrates (including oysters)	---	300-800	<3,000	All year

(from: Chamberlain and Doering, (1998)

- A distribution of inflows that has the greatest frequency of falling within the range of 300 to less than 1,500 cfs, with a peak flow range of 300-800 cfs, should be generally beneficial to all biota evaluated **(Table 9).**
- Since normal monthly wet season inflows are generally greater than 300 cfs, meeting this minimum flow limit only needs to be considered during the dry season.
- Some taxa (redfish, pink shrimp, blue crabs and benthos associated with *Vallisneria)* will receive the greatest benefit by being provided optimum inflows throughout the dry season, including winter months. However the majority of estuarine species are most productive and dependent on the estuary during the late dry season.
- Therefore, the greatest priority should be given to making the desired delivery in February to ensure that optimum conditions are available in the spring, and the required salinity regime has been established for *Vallisnaria* when it is most needed (Chamberlain *et al.* 1995).

Resource Functions Provided By Submerged Aquatic Vegetation

The beds of submerged aquatic vascular plants (SAV) that occur in rivers, lakes, estuaries and marine bays serve several important ecological functions which can be broadly categorized as 1) production and accumulation of organic matter; 2) creation of habitat structure; 3) reduction of wave and current energies; and 3) temporal buffering of nutrient cycles (Kemp *et al*.1984).

These grass beds add a physical complexity to shallow water habitats, provide a refuge from predation (Orth *et al*. 1992; Peterson 1982; Irlandi et al 1995) and serve as a nursery for young fish (Kemp *et al*. 1984). Leaves provide a substrate for settlement of invertebrate larvae (Heck *et al.* 1995) and growth of epiphytic algae (Kemp *et al*. 1984). In many aquatic ecosystems, submerged aquatic vegetation forms the basis for plant-based and detritus-based food webs (Zieman and Zieman 1989; Thayer et al 1984; Carter and Rybicki 1985). Given these ecological functions it is not surprising that the abundance and production of fish, invertebrates and waterfowl tends to be higher in grass beds than in adjacent unvegetated areas (Lubbers *et al*. 1990; Wicker and Enders 1995; Heck *et al*. 1995; Killgore *et al* 1989).

Submerged aquatic vascular plants can also provide water quality improvements. By baffling water motion, these grasses enhance sedimentation while their root/rhizome system stabilizes sediment (Carter *et al*. 1988; Fonseca and Fisher 1986). These effects on sediments result in reduced turbidity and enhanced water clarity (Ward *et al*. 1984; Carter *et al*. 1988). These SAV communities are also capable of rapid removal of nutrients from the water column. This buffering capability may damp nutrient input pulses from runoff events and reduce the potential for phytoplankton blooms (Kemp *et al.* 1984). The decay of vascular plant material proceeds at a relatively slow rate and thus creates a lower oxygen demand and releases nutrients back to the water column at a slower rate than more labile sources of detritus, such as phytoplankton (Twilley *et al*. 1985).

Freshwater inflows commensurate with healthy beds of *Vallisneria* also provide an open-water low salinity environment that serves a number of valuable resource functions. The larval and juvenile stages of many marine and estuarine species have adapted to withstand salinities of lower strength than adults. This adaptation allows these early life stages to occupy a low salinity region relatively free of predators (Gunter 1967). The strong relationships between size and salinity observed for many estuarine dependent species of fish and crustaceans indicates the value of low salinity regions for early life stages (e.g. Wagner and Austin, 1999). The presence of grass beds in tidal freshwater and low salinity regions greatly enhances utilization of these areas (Killgore *et al* 1989; Kemp *et al.* 1984). The longitudinal position of this low salinity zone has been used as an effective management tool of estuarine biological resources (Jassby *et al.* 1995).

Therefore, loss of the habitat functions listed above as a result of reduced dry season flows and increased salinity have the potential to result in some level of harm to Caloosahatchee estuary submerged aquatic vegetation communities and their associated fauna.

Literature Review Findings

One of the requirements for developing the MFL is to use “best available information.” A literature review was therefore conducted to (1) evaluate different approaches used to establish minimum flow requirements for other estuarine ecosystems, and (2) review the validity of using the Valued Ecosystem Component (VEC) approach to define MFLs for the Caloosahatchee Estuary. The literature review incorporated the following objectives (Estevez, 2000):

1. Identify those living estuarine resources that could potentially be used as indicators, targets, or criteria for determining a minimum flow in a riverine estuary
2. Determine how the selection of a living resource target may be affected in a system that has experienced a long history of extreme structural and/or hydrologic alteration.
3. Determine how to best apply lessons learned by other water management districts, other states, and other counties in establishing minimum flow criteria
4. Provide the District with an independent evaluation of the District’s approach for establishing a MFL within the Caloosahatchee River and Estuary. These recommendations are contained in the document entitled “A Review and Application of Literature Concerning Freshwater Flow Management in Riverine Estuaries” (Estevez, 2000).

Results of the literature review indicated the following:

- Very few published or unpublished accounts exist regarding the establishment of minimum flows in highly-altered riverine estuaries, especially when honoring the constraint that such a methodology must rely primarily on living resource.
- A literature of moderate size exists documenting specific estuarine impacts of flow alterations, but the majority of these address flow reductions. Contemporary work by other water management districts elsewhere in Florida is still in progress or being planned.
- Even though literature directly related to the Caloosahatchee River and Estuary is limited, the review provided relevant insights gathered from: (1) river science and instream flow determinations; (2) basic and applied estuarine ecology; (3) Texas estuaries studies; and, (4) Florida minimum flows and levels work in progress.
- A synthesis and application of these insights for the Caloosahatchee River and Estuary revealed that "habitat and indicator species approaches are working well in the Caloosahatchee River and

- The District has conducted important scientific work on *Vallisneria* (tapegrass) and *Thalassia* (seagrass) and has included considerations of shoal grass, oysters, and salinity variations in the Caloosahatchee River and Estuary.
- In light of the District goals, the Caloosahatchee River and Estuary should possess a permanent tidal freshwater, but not an extensive, persistent one. District work on submerged aquatic vegetation as a valued ecosystem component (VEC) has accomplished much and offers greater promise."
- The review provided two key observations: (1) the VEC approach is an appropriate method to use to determine a minimum flow and (2) the Caloosahatchee Estuary should possess a fresh-brackish water habitat. The VEC, *Vallisneria*, is indicative of this habitat and the water resource function the District desires to maintain.

Summary of Estuary Research Findings

Flow/Salinity Relationship

A one dimensional hydrodynamic/salinity model (Bierman 1993) was completed for the Caloosahatchee River and estuary and was used in the previous efforts, however, this model did not provide a satisfactory relationship of salinity and flow from S-79 under low flow (0 to 500 cfs) conditions for the inner estuary. Bierman's model was predicting higher salinity than was being observed in the Caloosahatchee River and estuary during low flow conditions. Therefore, District staff developed an empirical relationship between salinity at a given location in the estuary as a function of flow at S-79 (see memo from Ken Konyha, June 29, 2000, **Appendix A**). Flow data was obtained using measured flow from S-79 and salinity at the Ft. Myers Marina (22 km upstream of Shell Point) for the period from January, 1992 to November, 1999. The Ft. Myers Marina salinity station is located near a *Vallisneria* sampling station and is near the down stream boundary of the area with the greatest potential for growth of *Vallisneria*. Therefore, this salinity station was chosen for calibration of the statistical model. A scatter plot of modeled data vs. observed data reveals an R^2 of 0.76 (**Figure 9)** while **Figure 10** traces modeled data and observed data for the period of record.

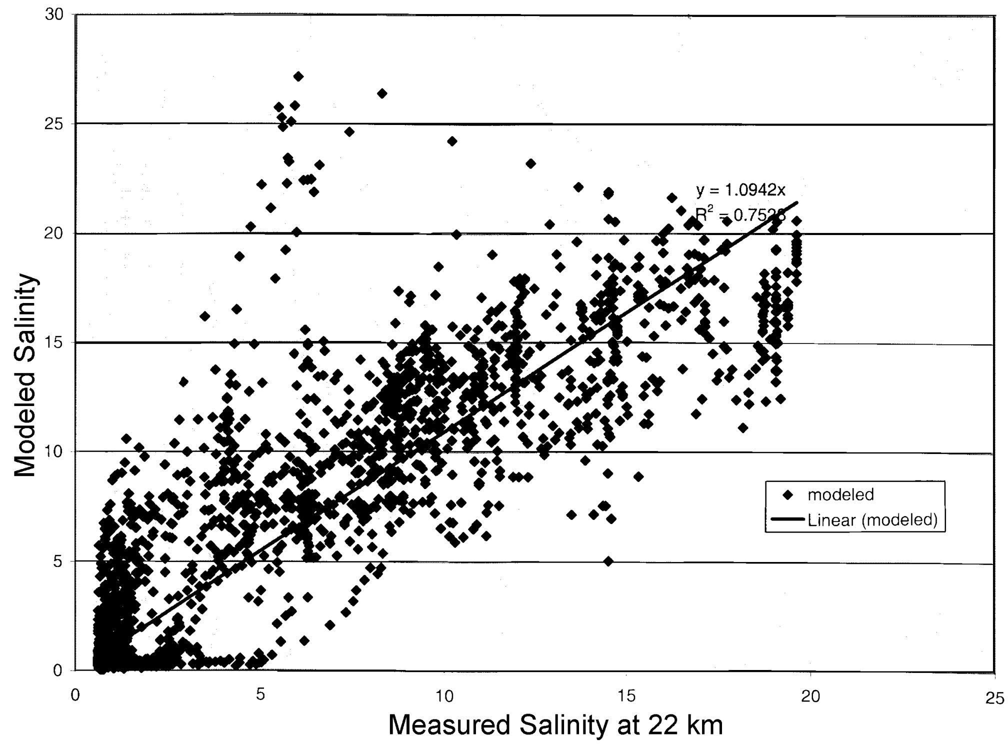

Figure 9. Scatter Plot of measured versus Modeled Salinity at 22 km upstream of Shell Point, Caloosahatchee Estuary

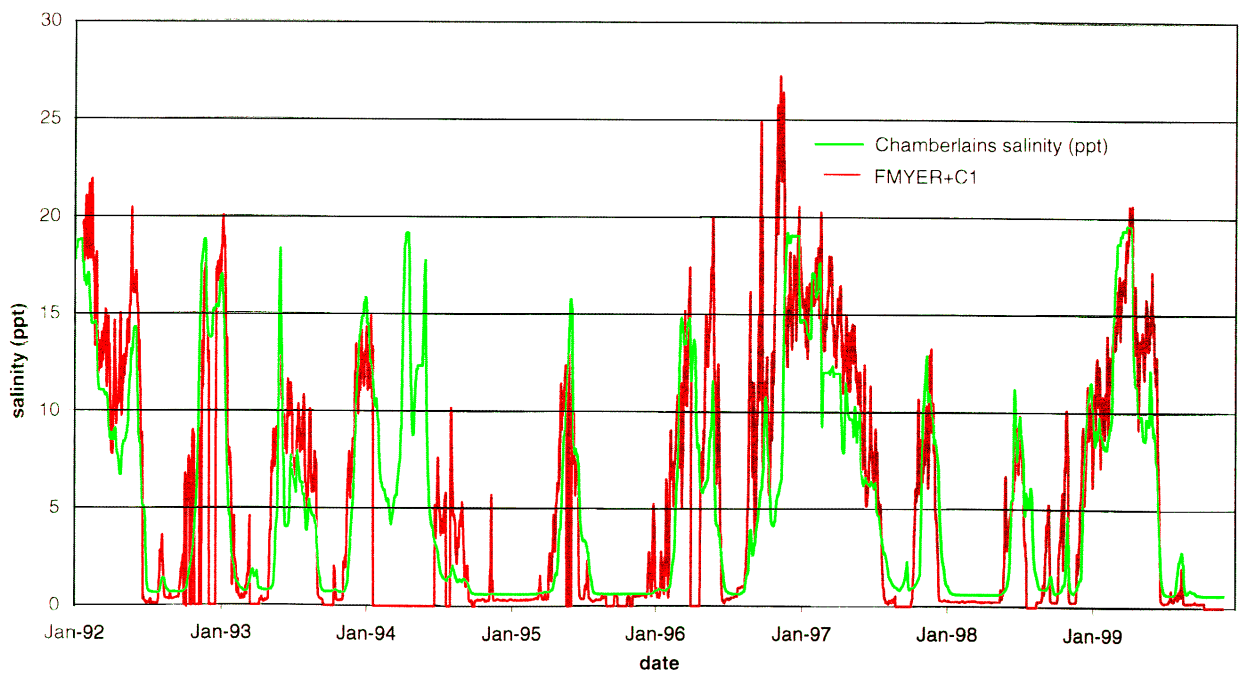

Figure 10. Comparing modeled to measured salinities at x = 22 km (based on Chamberlain's algorithm)

A comparison of predicted salinity from the two models in the area of concern, under steady state low flow conditions reveals that the District's model predicted significantly lower salinity under low flow conditions which better represented field observations. Therefore, this model was used to estimate salinity resulting from the predicted time series of flows from S-79.

Field and Laboratory Research

Vallisneria is a freshwater aquatic grass that is tolerant to low salinity and therefore, is frequently found in the transitional zone from freshwater to oligohaline habitats. Since *Vallisneria* grass beds are sedentary and salinity varies in response to inflows, understanding its tolerance to salinity is important in predicting its distribution and density. A literature search was conducted on the biology and life history of *Vallisnaria* to determine if its salinity tolerance information was adequate to avoid the need for additional field and laboratory investigations (Bortone, 1998; Doering *et al.*, 1999). While there have been several determinations of salinity tolerance of *Vallisnaria*, (Bourn, 1932; 1934; Haller *et al*., 1974; Twilley and Barko, 1990) estimates did not agree and there was little information about factors that might modify salinity tolerance. However, qualitative data for the Caloosahatchee Estuary indicate that densities decline when salinity is above 10 ppt and growth ceases at 15 ppt (Doering *et al*., 1999).

Qualitative data collected from the Caloosahatchee Estuary are consistent with these limits and indicates that densities decline when salinity is above 10 ppt. Since limited detailed information was available on the effects of varying salinity and duration of salinity exposure on *Vallisneria,* a field sampling program, was initiated to measure salinity and *Vallisneria* shoot density as well as other growth parameters at four locations along the salinity gradient. During the first year (1998) of field sampling (Bortone 1999), plants thrived since they were not exposed to salinity high enough to cause mortality. During 1999 however, dry season salinity data documented the effects of salt water intrusion, thus providing a data set for calibration of a *Vallisneria* growth and mortality model being developed with data from laboratory experiments.

In addition, the District conducted laboratory experiments (mesocosm studies) that simulated typical saltwater intrusions during the dry season (Doering *et al*., 2000). The results of these efforts are summarized as follows:

- In general, short duration intrusions (1, 5, 11 days) retarded *Vallisneria* growth, but did not cause significant mortality. Longer-term intrusions (20, 30, 50, 70 days) caused mortality, with the degree of mortality proportional to the duration of the intrusion.
- A 70-day exposure to 18 ppt caused an 80 percent loss of shoots. Nevertheless, observation of plants for another month at a favorable salinity (3 ppt) showed that viable plants remained even after 70 day at 18 ppt.
- Results of this field work indicate that *Vallisneria* can probably survive most salinity intrusions in the upper estuary. These studies also indicate that a 70-day intrusion is near the limit of what might be tolerated without a net population reduction during the winter. It would take the remaining plants 90-days of growth to reach pre-intrusion levels. The intrusion and recovery from it (70 + 90 =160 days) would occupy nearly the entire dry season (180 days).
- These experiments helped to not only to quantify the magnitude of minimum flows, but also provide information about the duration and timing of their delivery.

***Vallisneria* Growth Rate Algorithms**

In addition to above work, *Vallisneria* daily growth rate algorithms were developed relating changes in blade length, blade density and shoot density to salinity (memo from P. Doering, March 22, 2000 **Appendix A**). Although algorithms were established for all growth parameters, this evaluation only used shoot density predictions since it is the most appropriate measure of abundance. The main purpose of the evaluation was to predict decreases in abundance (mortality) due to salinity and not to reproduce the annual cycle of *Vallisneria* abundance. Because the model was not intended to reproduce an annual cycle of abundance, shoot density was 'reset' each year to a specified value every October. In general then, a 31-year simulation of *Vallisneria* shoot density identifies those years in which dry season salinity would have caused decreases in abundance. Specifically, the calibrated model best represents effects of salinity on the abundance of *Vallisneria* during the early spring portion of the dry season when this resource function is most needed. More details and results of this work are presented in **Appendix A (**memo from P. Doering, March 22, 2000; memo from K. Konyha , June 29, 2000).

PROPOSED MFL CRITERIA FOR THE CALOOSAHATCHEE RIVER AND ESTUARY

The following minimum flow criteria were developed for the Caloosahatchee River and Estuary based on the following assumptions and interpretation of data.

Importance to the Region

Tape grass (*Vallisneria americana)* beds located within the upper Caloosahatchee Estuary represent an extremely important estuarine habitat found within the greater Charlotte Harbor area. This submerged aquatic vascular plant community serves as critical nursery habitat during the spring months for a wide variety of estuarine species that are both commercially and recreationally important to the region (Bortone and Turpin 1998). The largest abundance of *Vallisneria* (640 acres) occurs from Beautiful Island to just past the Ft. Myers bridge. *Vallisneria* grass beds have been documented as an important component of upper and mid-estuary for more than 43 years (Phillips and Springer 1960; Gunter and Hall 1962). Its distribution and abundance varies in response to salinity, light penetration, and the amount of freshwater input (Chamberlain *et al*. 1995, Hoffacker, 1994; Doering *et al.* 1999). It is well documented that submerged aquatic vegetation, such as *Vallisneria,* provides important habitat for benthic invertebrates, small forage fish and shellfish and serves as a nursery area for many juvenile species that are commercially or ecologically important (Day *et al.* 1989). Previous research (Chamberlain *et al.* 1995) concluded that the majority of estuarine species within the upstream estuary are most productive and dependent on *Vallisneria* grass beds during the spring. Therefore, maintaining *Vallisneria* shoot density during this critical time period is a key issue for protecting this community against significant harm. In addition, the West Indian manatee, a federally protected endangered species, have been observed feeding in these grass beds during the winter months. Therefore, this area may also be an important feeding location close to a warm water refuge (FP&L power plant) for this protected species.

Definition of Impact

During dry periods when the river provides extended low flow or zero flow conditions, salinity within these grass bed communities gradually increase and over time, result in leaf defoliation and a reduction in the density (number of shoots/m^2) of *Vallisneria* (Doering *et al*. 1999; Doering *et al*. 2000). In this regard, loss of this habitat function within the estuary for several years in succession implies that the organisms that depend on it experience some level of harm each time this event occurs and do not have the opportunity for full recovery until suitable habitat is again present during the critical months. If loss of the habitat function continues indefinitely, then the species/life history stages that depend on it will eventually be eliminated from, or greatly reduced in numbers within this estuary. Best professional judgment was used to derive a threshold density of 20 shoots/m^2, below which the *Vallisneria* community no longer provides adequate habitat for estuarine organisms (Haunert *et al.* in review).

Significant harm to the habitat function implies that the organisms that would have utilized *Vallisneria* grass beds will be harmed or damaged or eliminated to an extent that multiple years will be required for the population to recover. Loss of a single year class of organisms could be significant harm if there was evidence that it would take several years for the population to recover from this setback. However, we do not have sufficient quantitative population data to make this determination for any species or group of organisms within the Caloosahatchee estuary.

Flow/Salinity Requirements

Results of District research efforts (see Konyha memo June 26, 1999 in **Appendix A**) have concluded that to maintain *Vallisneria* habitat that will support both estuarine and juvenile marine organisms, a minimum mean monthly flow of at least 300 cfs is required to be delivered to the estuary between the months of November – March (dry season). This requirement is based on Chamberlain *et al.* 1995 who reported the following:

- A minimum (mean monthly) flow of 300 cfs for *Vallisneria* will not be harmful to the various types of estuarine biota found within the estuary (**Table 9**), but [mean monthly] inflows greater than 2,500–3000 cfs would be detrimental to the community anytime of year.
- If the vast majority of flows range between 300 and 800 cfs, then the minimum discharge necessary to support *Vallisneria* will be attained.
- Since normal wet season mean monthly flows are usually greater than 300 cfs, meeting this inflow limit only needs to be considered during the dry season.

DEFINITION OF HARM AND SIGNIFICANT HARM

In order to establish technical criteria for determining a minimum flow for the Caloosahatchee River and estuary, it is necessary to define harm and significant harm for the habitat function of the *Vallisneria* community. Minimum flow and level criteria for the Caloosahatchee estuary are based on protection of submerged aquatic vegetation, *Vallisneria americana*. Previous research (Chamberlain *et al.* 1995) concluded that the majority of estuarine species within the upstream estuary are most productive and dependent on tape grass beds during the spring (November – March). Therefore, maintaining *Vallisneria* shoot density during this critical time period is the focus of this evaluation. At present, our best available information on the freshwater needs of *Vallisneria* is based on results obtained from a review of the literature and the three models described above -- a hydrologic model, a salinity model and a *Vallisneria* growth model. Definitions of harm and significant harm have been developed (Haunert *et al*. in review) based on predicted impacts to the habitat function of the *Vallisneria* community:

Definitions

- *Vallisneria* shoot density in critical grass bed areas (between 15 and 19 mile upstream of Shell Point) may periodically fall below 20 shoots/m^2 during the months of March, April and May. Such events may be stressful, but are considered to be within the range of normal fluctuation and do not constitute harm. Organisms have the ability to recover during the following wet and dry seasons in response to increased flow.
- It is the expert opinion of District biologists that ***harm*** occurs if such an event happens during two consecutive years. This degree of habitat loss will impact local populations within the Caloosahatchee estuary of species that live for one or two years and are highly dependent on this freshwater habitat during the spring months to successfully grow or reproduce (**Table 10**).

Table 10. Fish and Crustaceans that may Benefit from Low Salinity and Utilization of *Vallisneria* Habitat within the Caloosahatchee Estuary during the Spring.

Species	Relative Abundance	Spawning	Relative Utilization	Life Span
Important Forage for Game Fish				
Penaeus duoraum (Pink shrimp)	Abundant as juveniles	Apr-Sep	High	2 yrs
Palaemonetes pugio (Grass shrimp)	Highly abundant (eggs, larvae, juveniles, adults)	Feb-Oct	High	1 yr
Callinectes sapidus (Blue Crab)	Highly abundant juveniles; abundant adults	Apr-May; Sep-Oct	High	3-4 yrs
Brevoortia smithi (Yellowfin menhaden)	Common as juveniles	Feb-Mar	High	5-12 yrs
Anchoa mitchilli (Bay anchovy)	Highly abundant all life stages	Feb-Mar; Jun-Aug	High	1-2 yrs
Fundulus grandis (Gulf killifish)	Common all life stages	Nov-May	High	3 yrs
Menidia sp. (Silversides)	Highly abundant all life stages	Mar-May; Oct-Nov	High	1-2 yrs
Lagodon rhomboides (Pinfish)	Highly abundant as juveniles; common as adults	Oct-Feb	High	?
Mugil cephalus (Striped mullet)	Highly abundant as juveniles	Dec-Feb	High	7-8 yrs
Game Fish				
Megalops atlanticus (Tarpon)	Abundant as juveniles	Mar-Apr	Medium	15 yrs
Centropomus undecimalis (Snook)	Abundant as juveniles; common as larvae	Jun-Jul	Low	5-7 yrs
Bairdiella chrysoura (Silver perch)	Abundant larvae and juveniles	Mar-Apr; Aug-Sep	Medium	6 yrs
Cynoscion arenarius (Sand seatrout)	Abundant as juveniles	Mar-May; Aug-Sep	High	3 yrs
Cynoscion nebulosus (Sea trout)	Common as juveniles and larvae	Apr-Jun; Aug-Sep	Low	15 yrs
Pogonias cromis (Black drum)	Common as larvae and juveniles	Jan-Apr	High	58 yrs
Sciaenops ocelatus (Red drum)	Common as larvae; abundant as juveniles	Sep-Oct	High	Over 37 yrs

Source: Patillo, M.E. et al. 1994. Distribution and abundance of fishes and invertebrates in Gulf of Mexico Estuaries, Vol. II: Species Life history summaries. ELMR Rept. No. 11. NOA/NOS Strategic Environmental Assessments Division, Silver Spring, MD. 355 p.

- Similarly, it is the expert opinion of District biologists that ***significant harm*** occurs if the habitat function of this community is lost for three consecutive years or more. Many estuarine and marine species which utilize this habitat have life spans of three years or less and represent important forage organisms which support higher trophic level species (**Table 10)**. These organisms are highly dependent on this freshwater habitat during the spring months and may fail to reproduce successfully during their lifetime if this habitat is lost or reduced.

Support for the levels of harm discussed above are derived from a review of the life histories of important forage species and game fish that utilize either open-water or grass bed habitats in the low salinity region of the Caloosahatchee estuary during the spring (**Table 10).** The forage species that typically have the highest biomass are: bay anchovies, silversides, and pink shrimp. The life span of these species is about two years. The most estuarine dependent game fish (sand sea trout) has a life span of three years. All of these species have a bimodal or extended spawning cycle. Usually the spring spawn is the most intense and therefore most important. One purpose of the proposed MFL is to provide favorable habitat and sufficient productivity to support larval/juvenile development during this important spring spawning and growout period. Loss of this habitat over consecutive years will adversely affect the secondary productivity of the estuary especially for those species with short life spans (i.e., 2-3 years). Based on the available information, District staff believe that loss of the spring spawn/growout for one life span may constitute harm for a particular species but that three consecutive years of loss of this habitat constitutes significant harm for the *Vallisneria* community.

In addition, Estevez (2000) reports that it is now understood that native aquatic biodiversity depends on maintaining or creating some semblance of natural flow variability, and that native species and natural communities will perish if the environment is pushed outside the range of natural variability. Where rivers are concerned, a natural flow paradigm is gaining acceptance. The full range of natural intra- and interannual variation of hydrologic regimes are critical in sustaining the full native biodiversity and integrity of aquatic ecosystems. There is a growing sentiment for a similar paradigm in estuaries. In riverine estuaries it seems reasonable to evaluate both flows and salinity with respect to their multiple forms of variation. The District is in the process of developing a natural systems model for the Caloosahatchee Basin which predicts 30 years of flow with natural landscape features in the watershed prior to drainage and development of the region. In concert with salinity and plant growth models, this model will be used to develop a better understanding of historic return frequencies of low flow conditions that impacted *Vallisneria* communities prior to construction of the C-43 canal.

Modeling *Vallisneria* Response to Simulated Flow Conditions

The next step taken by District staff was to incorporate Chamberlain's empirical flow/salinity relationship and Doering's *Vallisneria* growth rate algorithms into a regional hydrologic model (South Florida Water Management Model or SFWMM) to simulate tape grass growth under simulated flow conditions at various locations within the estuary. Using the above definitions of harm and significant harm, District staff determined how often these criteria would be exceeded under current and future conditions.

Regional Modeling Approach

Several regional and sub-regional plans have been recently completed for South Florida by the SFWMD and the United States Army Corps of Engineers (USACE). The USACE and the District developed the "Comprehensive Everglades Restoration Program" (CERP a.k.a. the "Restudy"), which provides engineering solutions (improvements) to address water management problems in South Florida (USACE & SFWMD, 1999). The SFWMD, while considering CERP, also developed a number of regional water supply plans for the Lower East Coast, Lower West Coast and Caloosahatchee planning areas (SFWMD, 2000b, 2000c, 2000d). Major efforts were made to develop these plans using consistent data and performance measures. The Caloosahatchee estuary watershed is within the geographical boundaries of all four plans. A common base case and future base case scenarios were generated for these plans using the South Florida Water Management Model (SFWMD 1999).

The 1995 base case includes a 31-year historical period of record (1965-1995) with 1995 land use and current water management operations. A future base case (2020 with Restudy) was also developed and includes future 2020 land uses as well as the majority of the CERP improvements (reservoirs, aquifer storage and recover, and back pumping) planned for the C-43 basin. Therefore, both of these modeling scenarios can simulate flows discharged from S-79 to the Caloosahatchee estuary under current and future with Restudy conditions.

IN the 2020 with Restudy simulation, a number of environmental flow requirements were incorporated into the model scenario for the Caloosahatchee watershed (see Konyha memo, June 1999, October 1999, and January 2000, **Appendix A).** These estuarine flow requirements were determined from previous District research and included the desired range of flows of 300 to 2800 cfs plus natural variation outside of this desired range (Chamberlain *et al.* 1995). **Figure 11** shows a frequency distribution of flows for both the 1995 and the 2020 with Restudy cases.

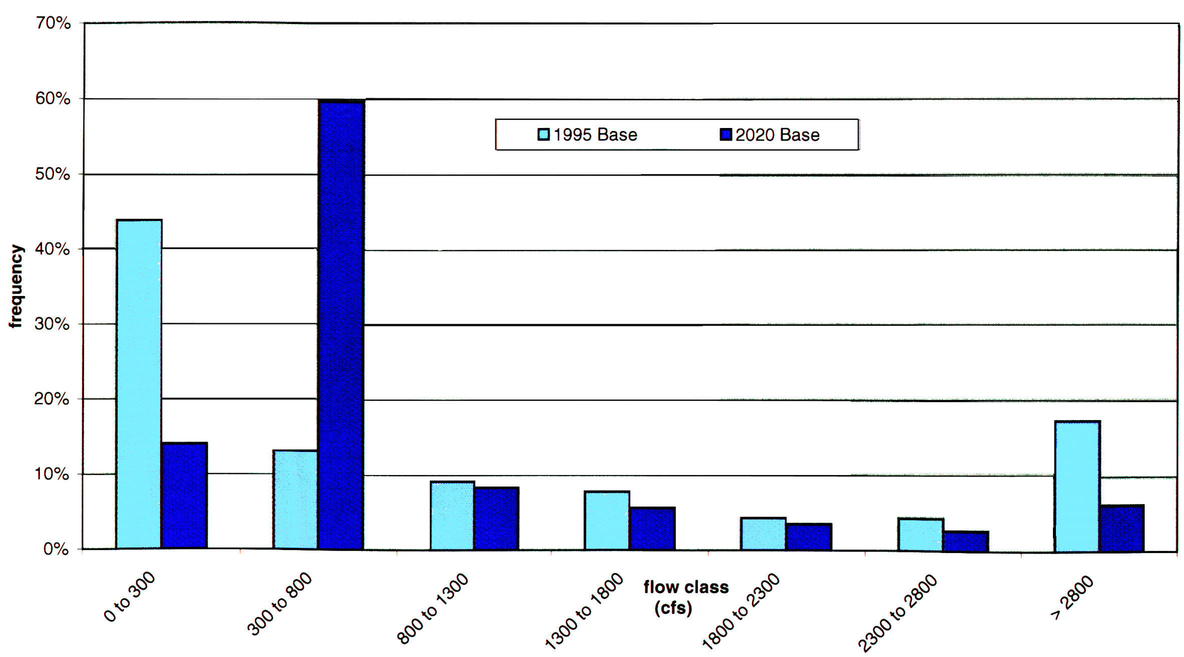

Figure 11. Frequency Distribution of Monthly Flows for the 1995 Base Case and 2020 with Restudy Components

The major changes in flow shown in the 2020 with Restudy histogram included a dramatic increase in base flows and flows within the range of 300 to 800 cfs, and a significant decrease in flows greater than 2800 cfs. All of these changes in flows are consistent with District estuarine research recommendations.

Modeling *Vallisneria* Response to S-79 Flows

Incorporation of the flow/salinity relationship and *Vallisneria* growth rate algorithms into the SFWMM, the District could then simulate tape grass growth under various simulated flow conditions to assess (a) how often levels of harm and significant harm were exceeded as well as (b) determine how much additional flow would be needed to deliver to the estuary to prevent significant harm. This was simulated using three 31-year time series of flows to simulate *Vallisneria* shoot density in areas where it would grow when favorable salinity conditions exists. The three time series included: (a) the 1995 base case, used to determine how frequently *Vallisneria* communities are impacted under current conditions, and how frequently additional flows would be needed to be delivered to the estuary to avoid significant harm; (b) the 1995 base with additional flows to avoid significant harm; and (c) the 2020 with Restudy future case, which included the CERP improvements in the watershed as a MFL Recovery and Prevention Strategy to avoid significant harm conditions.

The first area downstream of S-79 that has high potential (appropriate depths and bottom types) for *Vallisneria* to flourish is from 15 to 19 mi upstream from Shell Point. In this area, *Vallisneria* currently populates about 640 acres with the greatest portion of this acreage occurring within the first several km (**Figures 12 and 13)**. The three time series of flows were used to predict salinity in this 640 acre area. **Figure 14** reveals that predicted salinity at the boundaries of the 640 acre area (15 and 19 km) for the base case differed by less than 1 ppt. Due to this limited difference in salinity, the predicted *Vallisneria* shoot density was also limited. Therefore, shoot density (abundance) at the most downstream location (15 km) will be considered a conservative indication of the abundance in the 640 acre area.

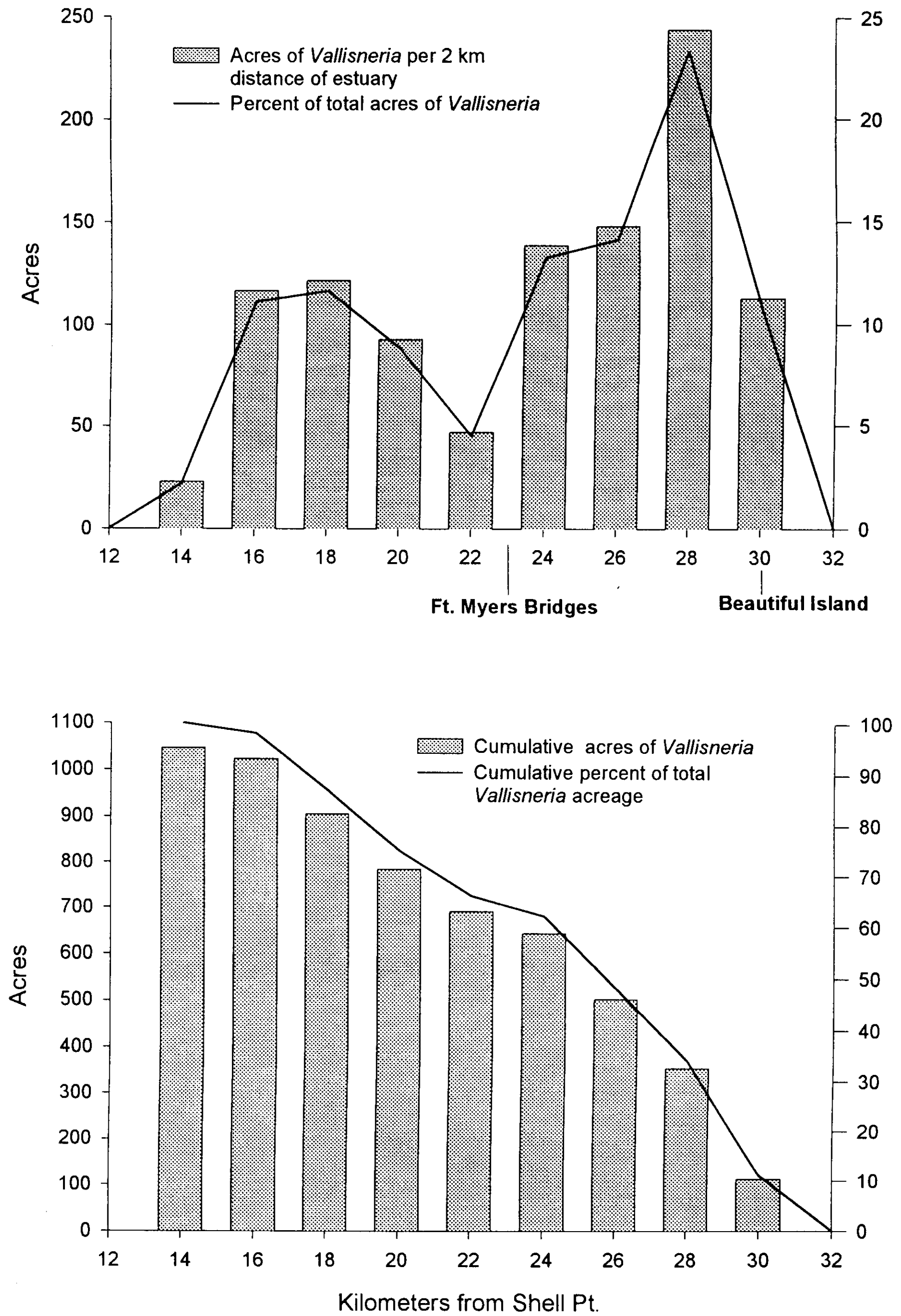

Figure 12. Estimated maximum *Vallisneria americana* coverage in the Caloosahatchee Estuary during ideal environmental conditions.

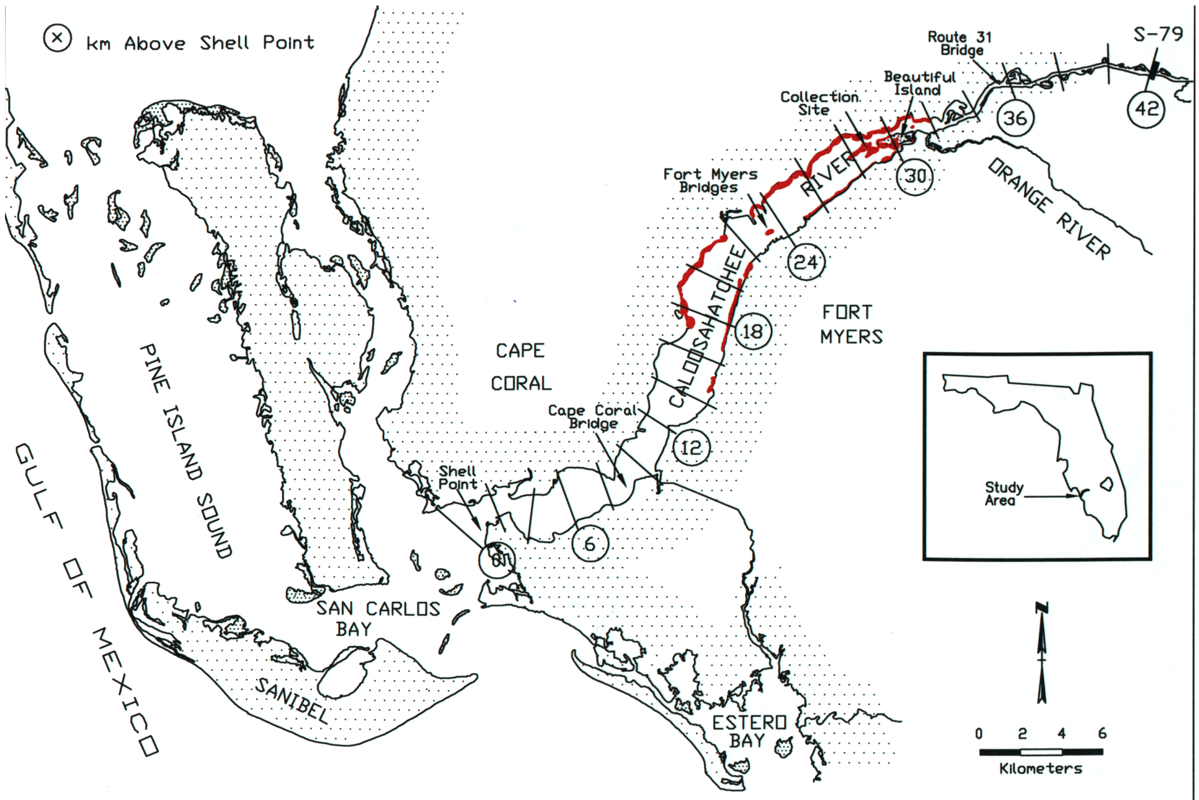

Figure 13. ***Vallisneria americana*** **distribution in the Caloosahatchee estuary**

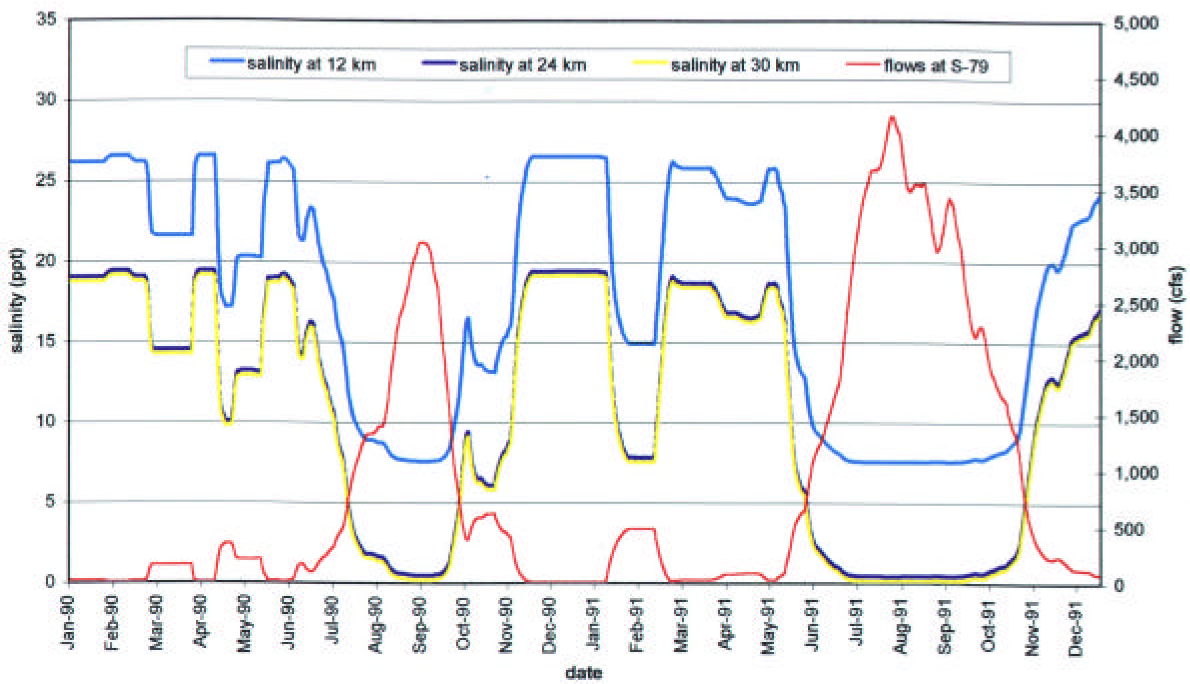

Figure 14. Salinity estimates based on 1995 base case flows at. S-79 at three locations upstream of Shell Point, Caloosahatchee Estuary

Exceedances of Harm and Significant Harm

By reviewing SFWMM output for the 1995 Base Case flows, predicted salinity values at15 miles (24 km) upstream from Sheell Point, and predictions of *Vallisneria* shoot density and salinity a determination was made of conditions that were associated with low shoot densities in the spring (**Figures 15 and 16).**

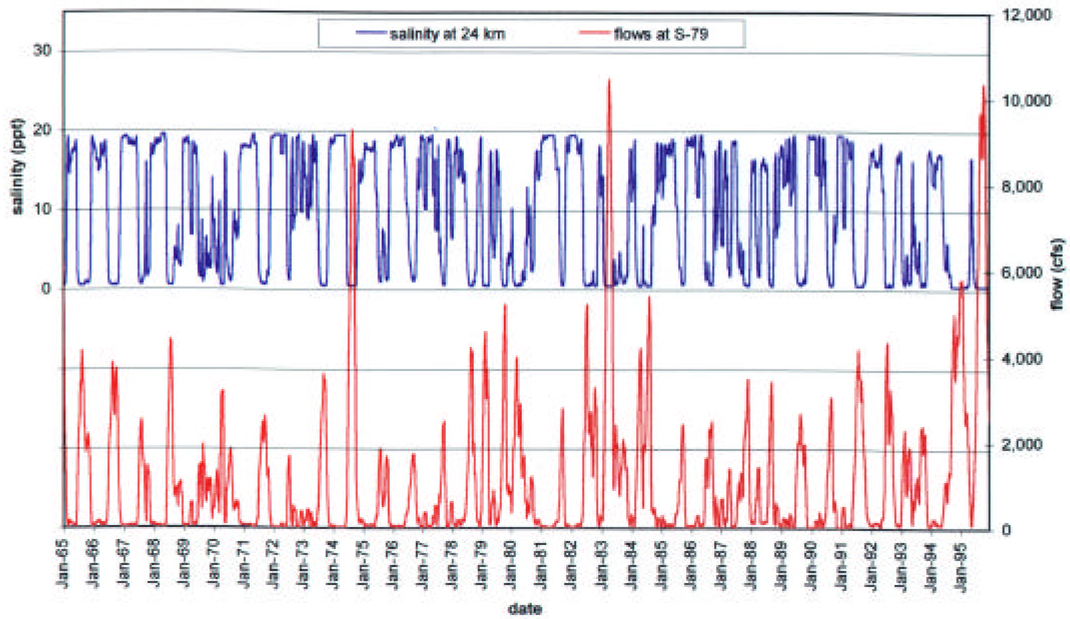

Figure 15. Salinity estimates based on 1995 Base Case flows at S-79, 15 Mi. upstream of Shell Point, Caloosahatchee Estuary

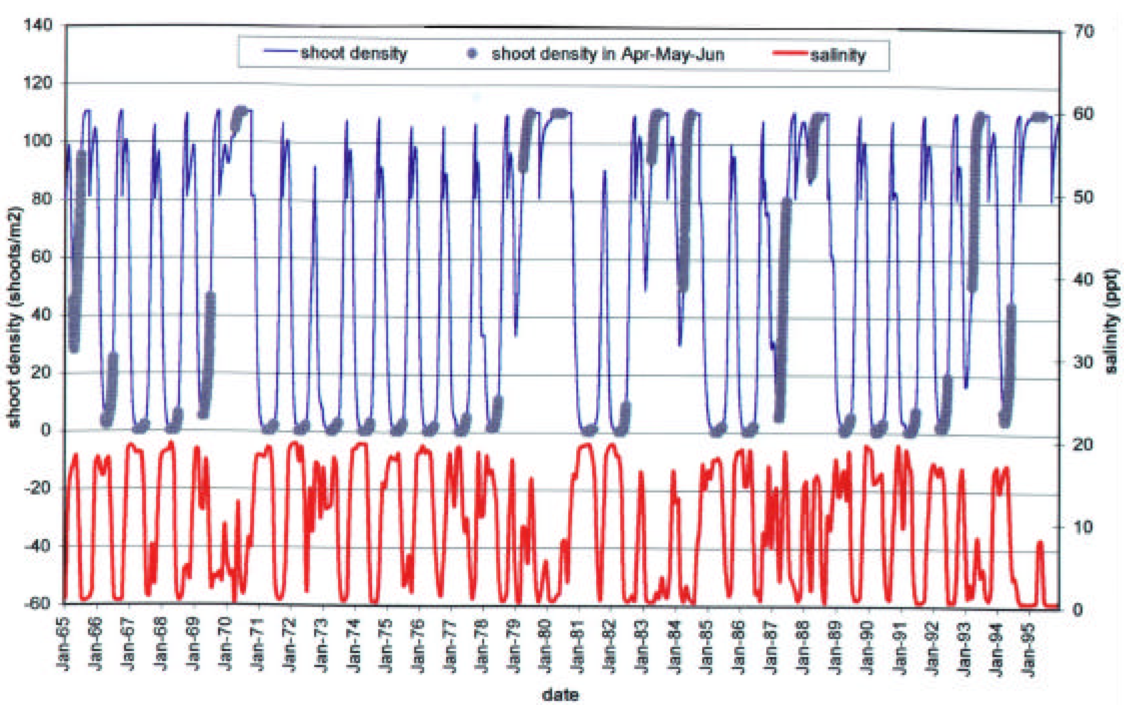

Figure 16. 1995 base case- *Vallisneria* shoot density and salinity 15 Miles upstream of Shell Point, Caloosahatchee Estuary

The data were further analyzed to determine how often the proposed *harm* and *significant harm* definitions were exceeded within the Caloosahatchee estuary under the 1995 Base Case. **Figure 16** shows the predicted *Vallisneria* shoot densities 15 mi upstream of Shell Point resulting from 1995 Base Case flows from S-79. These densities indicate the response of *Vallisneria* to current District water management operations. Using the threshold shoot density of less than 20 shoots/m^2 to indicate loss of the habitat function during the spring, the 1995 Base Case (**Figure 16)** showed that current water management operations result in 22 events when shoot densities decline below 20 shoots/m^2 during the 31-year simulation (frequency of once every 1.4 years). The conditions of ***harm*** defined above (loss of habitat function two years in succession with less than 20 shoots/m2) occurred 16 times (once every 1.94 years) (**Table 11, Figure 16**). ***Significant harm*** (loss of habitat function three years in succession with less than 20 shoots/m2) occurred 11 times (once every 2.8 years) during the period of record **(Table 11**).

Table 11. Determining Years that Could be Managed to Avoid Significant Harm - Current Conditions (1995 BASE) and Restored Conditions (2020 RESTUDY).

	1995 Base			Adaptive Water Management Approach			2020 RESTUDY		
Year	Stress[1]	Harm[2]	Significant Harm[3,4]	Stress[1]	Harm[2]	Significant Harm[3]	Stress[1]	Harm[2]	Significant Harm[3]
1965									
1966	Y			Y					
1967	Y	Y		Y	Y				
1968	Y	Y	Y	*					
1969	Y	Y	Y	Y					
1970									
1971	Y			Y					
1972	Y	Y		Y	Y				
1973	Y	Y	Y	Y*	Y	Y	Y		
1974	Y	Y	Y	Y					
1975	Y	Y	Y	Y	Y				
1976	Y	Y	Y	*					
1977	Y	Y	Y	Y					
1978	Y	Y	Y	Y	Y				
1979									
1980									
1981	Y			Y			Y		
1982	Y	Y		Y	Y				
1983									
1984									
1985	Y			Y					
1986	Y	Y		Y	Y				
1987	Y	Y	Y	*					
1988									
1989	Y			Y			Y		
1990	Y	Y		Y	Y		Y		
1991	Y	Y	Y	*			Y		
1992	Y	Y	Y	Y					
1993									
1994	Y			Y					
1995									
total	22	16	11	17	7	1	4	0	0

[1]Stress occurs if the minimum shoot density in Apr-May-Jun is <20 shoots per square meter
[2]Harm occurs if there is stress in two consecutive years.
[3]Significant harm occurs if there is stress in three consecutive years.
[4]Effective management during critical years would eliminate significant harm

* Water added to 1995 Base Case in an effort to avoid significant harm

Results of this analysis indicate that under current operating conditions, as simulated by the 1995 Base Case, additional flows are needed during most years to prevent ***harm*** and ***significant harm*** from occurring to the resource function provided by the *Vallisneria* community in the Caloosahatchee Estuary. Therefore a MFL Recovery and Prevention strategy is required.

MFL RECOVERY AND PREVENTION STATEGY

Adaptive Water Management Approach

Since benefits from the implementing the MFL Recovery and Prevention Strategy (described below) will not occur until 2012, when structural elements of CERP are completed, the District should consider implementing an interim water management strategy to address MFLs. In the LEC Regional Water Supply Plan, the following description of a recovery strategy for the Caloosahatchee estuary was provided (SFWMD 2000 Planning Document, P 228)

> "In the period of time prior to construction of these facilities, the District will utilize water in Lake Okeechobee, when available, for releases to the Caloosahatchee River to prevent MFL violations, which are projected to occur only during extreme droughts. In implementing this interim recovery and prevention strategy, releases to prevent significant harm will occur as follows: if a die back of *Vallisneria* grass beds occurs in the area identified in the MFL criteria during one year, for at least one of the following two years, an average of 300 cfs of water will be delivered at the S-79 structure during the months of February through April"

The goal of the Adaptive Water Management Strategy (AWMS) proposed below is provide the details of how such an interim strategy can be implemented to better meet the MFL criteria. The intent is to reduce the occurrence of significant harm to the 640 acres of *Vallisneria* beds that are located between 15 and 19 mi upstream of Shell Point. To determine the flow rate and duration needed to achieve this goal, additional flows were added to the 1995 Base Case flow time series as needed. These flows were then used to predict salinity in the 640-acre area and the *Vallisneria* growth model was applied to predict abundance resulting from the additional flows.

A number of different flow rate and duration regimes (**Table 12**) were attempted with the models to arrive at the most favorable combination (see Konyha memo June 26, 2000 in **Appendix A**). Results from this effort revealed that eight combinations of flow rate and duration were able to eliminate 10 of the 11 occurrences of significant harm: combination b, d, e, f, l, q, r, and s. These had flows of 300 cfs, 350 cfs, 400 cfs, or 550 cfs. Effective starting and ending months depend on the flow threshold. These results showed:

- Flows of 300 cfs need to be applied from November through March (run f).
- Flows of 400 cfs need to be applied from December through March (run s).
- Flows of 550 cfs can be applied from December through February (run l).

The volume of supplemental flow was similar for all thresholds (68,000, 75,000, and

78,000 acre-feet for runs f, s, and l, respectively).

Of these three flow thresholds, the 300 cfs value is preferred because it requires less water and longer application periods are more likely to have incidental benefits. Such benefits may include: (a) improved water quality in areas of the river that are used for municipal water supply, and (b) a greater chance that basin runoff will reduce the demand for flow from the Lake.

It is a common practice to release large volumes of water from Lake Okeechobee over short time periods during the dry season to protect municipal water supply from salt water and/or undesirable algae blooms. The proposed minimum flow proposed in this report should help reduce the occurrence salt water intrusion and undesirable algal blooms in the river, thus eliminate or greatly reduce the need to make short-term, high volume releases in the dry season.

Table 12. Comparing the Effectiveness of Potential MFL Release Rules for Reducing the Occurrence of Significant Harm under "1995 BASE WITH MFL FLOWS".

RUN	Minimum Flow	High susceptibility period		Occurrences of significant harm		water added (ac-ft/y)
		Start	End	Count	Years	
a	0	-	-	11	(see Table 11)	0
b	300	Nov	Ma	1	1973	93,119
c	250	Nov	Ma	3	1968, 1973, 1976	76,027
d	350	Nov	Ma	1	1973	110,558
e	300	Nov	April	1	1973	81,295
f[1]	**300**	**Nov**	**March**	**1**	**1973**	**68,214**
g	300	Nov	Feb	4	1968, 1973, 1976, 1991	53,059
h	350	Nov	Feb	2	1968, 1973	63,032
i	300	Dec	Feb	4	1968, 1973, 1976, 1991	39,726
j	350	Dec	Feb	4	1968, 1973, 1976, 1991	47,219
k	500	Dec	Feb	2	1973, 1991	70,205
l	550	Dec	Feb	1	1973	78,003
m	300	Dec	March	4	1968, 1973, 1976, 1991	54,881
n	300	Dec	April	4	1968, 1973, 1976, 1991	67,962
o	300	Dec	Ma	4	1968, 1973, 1976, 1991	79,786
p	350	Dec	Ma	2	1973, 1991	94,746
q	400	Dec	Ma	1	1973	109,938
r	400	Dec	April	1	1973	93,247
s	400	Dec	March	1	1973	75,361
t	400	Dec	Feb	4	1968, 1973, 1976, 1991	54,804
u	400	Dec	Jan	4	1968, 1973, 1976, 1991	37,213
v	350	Dec	March	2	1973, 1991	65,065
w	400	Jan	March	4	1968, 1973, 1976, 1991	53,804
x	500	Jan	March	3	1968, 1973, 1991	68,783
y	550	Jan	March	2	1973, 1991	76,384
z	600	Jan	March	2	1973, 1991	84,029
aa[2]	300	Nov/Oct	March	0		71,829

[1]Run "f" is the best performing MFL release rule.

[2]Run "aa" eliminates significant harm in 1973 by starting releases in October, 1972 instead of November. Otherwise, run "aa" is identical to run "f."

Figure 17 shows the shoot density of *Vallisneria* resulting from implementing the recommended minimum flows that avoided significant harm 10 out of 11 times. An exceptional spring event occurred in 1973, when the season began with a shoot density below 20 shoots/m^2. In spite of this adverse condition, significant harm was nearly avoided by implementing the proposed water releases. Therefore, as a general adaptive rule, and considering that the methods used are not refined, District staff believe that the recommended flow rates and duration provide an acceptable level of resource protection.

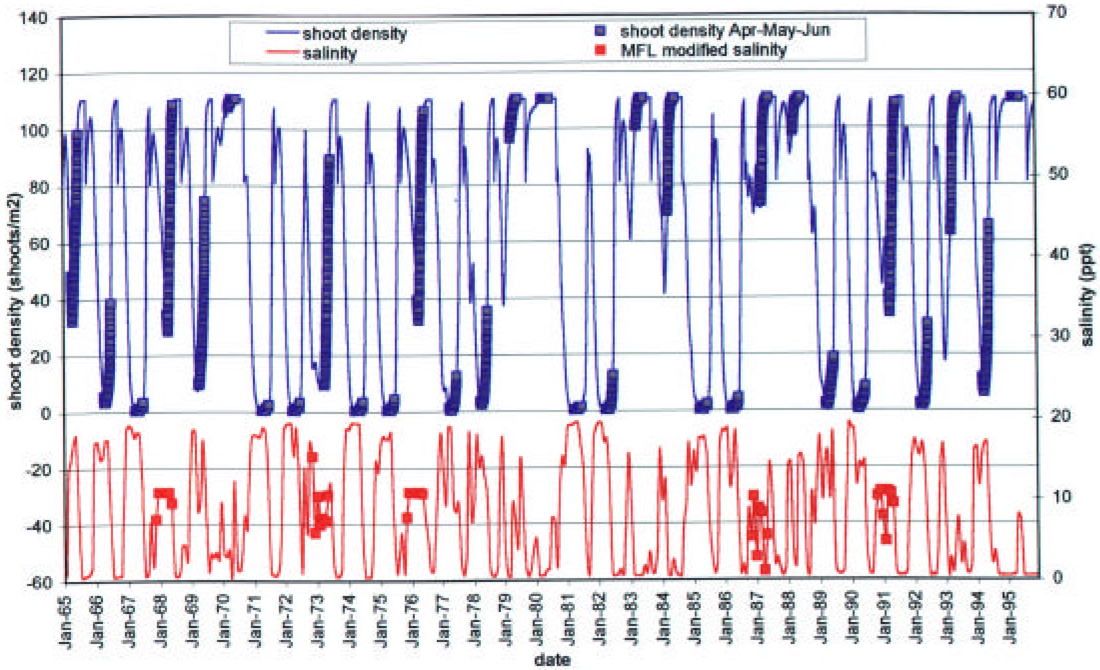

Figure 17. 1995 Base Case with MFL Flows – *Vallisneria* Shoot Density and Salinity at 15 mi Upstream of Shell Point, Caloosahatchee Estuary

With the present infrastructure and water demands, the flows needed to meet this goal come from Lake Okeechobee. Each November, the District should consider examining water supply conditions throughout the District and the status of *Vallisneria* communities within the Caloosahatchee Estuary over the last several years to determine the possibility making recommended minimum flow releases to the estuary. A biological monitoring program will be needed to continually assess the condition and response of *Vallisneria* and organisms that utilize this habitat, in relation to S-79 flow and salinity conditions within the 640 acre area. The District presently has real-time access to both flow and salinity data in this area, and ongoing *Vallisneria* studies are also in progress within the area. With information from these monitoring programs, we can fine-tune the relationship between flow/salinity and *Vallisneria* abundance and thus adapt District operational protocol to make these deliveries in order to avoid significant harm to water resource functions of the Caloosahatchee estuary.

Water management operational rules for meeting minimum flow criteria from S-79 must be provided to ensure that the MFL goal for the estuary is met, while conserving water from Lake Okeechobee and using watershed runoff to the maximum practical extent. The total volume of water for a 30-day month with a flow rate of 300 cfs is 17,820 acre feet. Therefore, the operational procedure proposed to meet minimum flows is as follows:

1. Determine total volume of releases from S-79 for the previous three weeks
2. If volume is below 13,365 ac ft., an average pulse release of 300 cfs (i.e. ranging from 100 to 600 cfs) for the following week
3. If volume is between 13,365 and 124,835 ac ft., an average pulse release of 200 cfs for the following week
4. If volume is between 14,835 and 16,305 ac ft., an average pulse release of 100 cfs for the following week
5. If volume is between 16,305 and 17,820 ac ft., an average pulse release of 50 cfs for the following week
6. If volume is greater than 17,820 ac ft., do not release minimum flows for the following week
7. If during a minimum flow release a storm event provides significant runoff to the estuary, minimum flows should be terminated until the following weeks evaluation.

This procedure would be followed in concert with the monitoring program to ensure adaptability in meeting the MFL goal.

Recovery and Prevention Strategy

Because the proposed minimum flow criteria can not be met every year under current conditions, a Recovery and Prevention Strategy is needed. As previously mentioned, the SFWMD is involved in four major water management plans that require a consistent future water management scenario for the Caloosahatchee Estuary watershed. The proposed future development of water resources within the Caloosahatchee watershed will be designed to reduce the watershed's reliance on Lake Okeechobee water while providing optimal flows (including dry season flows nearly every year) as described in Haunert *et al.* (in review), to the estuary. The future year 2020 with Restudy scenario includes the following design elements within the Caloosahatchee watershed as outlined in CERP (USACE and SFWMD, 1999).

Reservoir – The reservoir is 10,000 acres in area with a 16 ft depth and a capacity of 160,000 acre-feet. Waters are pumped from the C-43 canal into the reservoir using a pump with a 2,500 cfs capacity. The reservoir is located in the West Caloosahatchee Drainage Basin. The operating rules for the reservoir are based on reservoir storage and basin runoff.

Aquifer Storage and Recovery (ASR) Wells - There are 22 sets of ASR wells each with a capacity of 10 mgd. These wells are used to inject waters from the reservoir or withdraw waters as needed from the aquifer. A 75% recovery is assumed, regardless of the period stored underground. It is assumed, that there is no mixing with higher salinity aquifer water. The operating rules of the ASRs are based on reservoir storage.

Backpumping – A set of pumps near the S-78 Structure lift waters from the reservoir and the West Caloosahatchee basin into the East Caloosahatchee basin. A second set of pumps lifts waters from the East Caloosahatchee basin through a storm-water treatment area (STA) into Lake Okeechobee. The pump capacity of these facilities is 1,000 cfs. Operating rules for the pumps are based on the reservoir storage volume.

These are generic design elements that may be replaced by alternate design elements in the future; however, the same optimal flow requirements for the Caloosahatchee estuary will be met regardless of a change in elements.

The schedule for construction of these facilities can be found in the "Central and Southern Florida Project Comprehensive Review Study (CERP), Appendix M, Implementation Plan Scheduling and Sequencing"(USACE and SFWMD 1999). In short, the construction of the reservoir and ASRs is scheduled to begin in 2005 and be completed in 2012. Construction of the backpumping facilities is planned to begin in 2012 and be completed in 2016.

Once the facilities are operational, the optimal flow requirements for the Caloosahatchee estuary will be realized. **Figure 18** shows the flows from S-79 and salinity at 15 mi upstream of Shell Point when the above construction elements are completed (2020 Restudy).

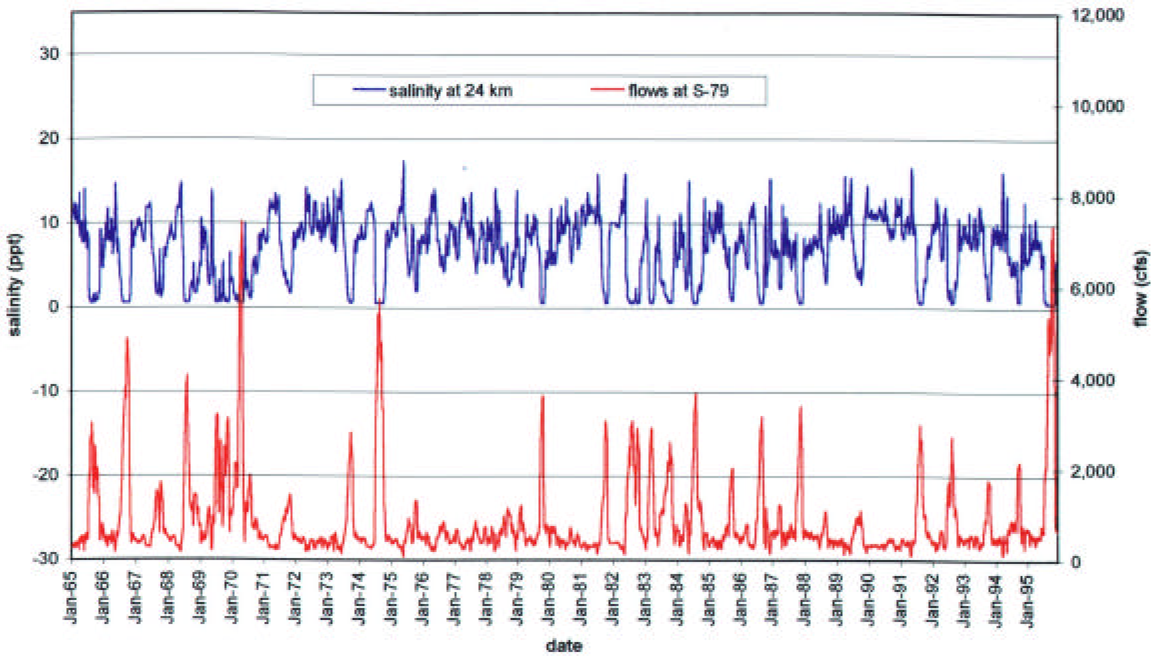

Figure 18. Salinity Estimated Based on 2020 with Restudy Flows at S-79, 15 mi Upstream of Shell point, Caloosahatchee Estuary

This 31-year time series reveals that the base flow of about 300 cfs is achieved for the majority of the simulation and that a significant reduction occurs in flows greater than 2,800 cfs, relative to the 1995 Base Case conditions in **Figure 16**. The proposed CERP components would largely accomplish the goals of promoting recovery and preventing significant harm to water resource functions of the Caloosahatchee Estuary. The base flows were sufficient to maintain salinity below 10 ppt most of the time in the 640 acre area that supports growth of *Vallisneria*. The predicted effect of these flows and salinity on shoot densities at location 15 mi is shown in **Figure 19** and **Table 11**. Using the definitions of ***harm*** and ***significant harm*** provided in this report, flows delivered to the estuary under 2020 with Restudy conditions result in only one exceedance of the ***significant harm*** criteria, and two exceedances of the ***harm*** criteria, over the 31-year simulation. Therefore, the proposed construction elements and revised operational features can be considered, in general, a major improvement compared to the 1995 Base Case condition (**Figure 16**). Implementation of this proposed adaptive management strategy (**Figure 17**), and the deployment of the proposed Caloosahatchee Basin Reservoir, ASR and Backpumping elements and their operational criteria by 2016, constitute a MFL Recovery and Prevention Strategy for the Caloosahatchee Estuary (Haunert *et al.* in review).

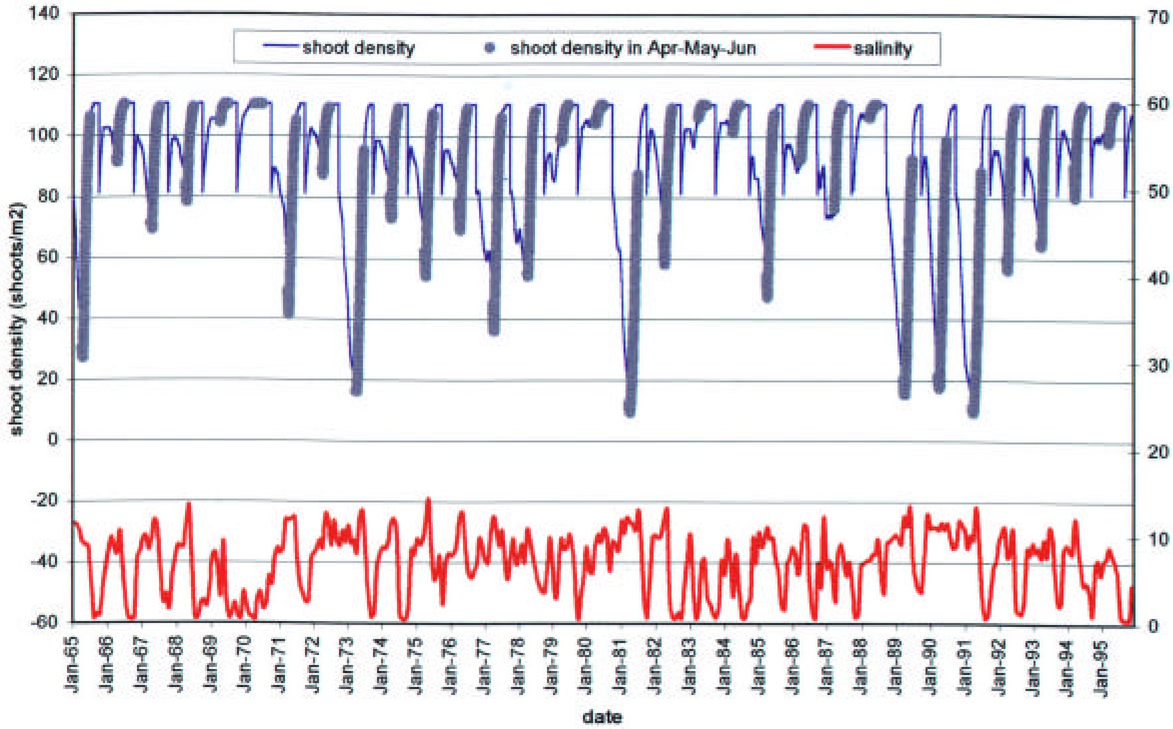

Figure 19. 2020 with Restudy- *Vallisneria* Shoot Density and Salinity, 15 mi Upstream of Shell Point, Caloosahatchee Estuary.